Module 1

- **Casting** is a manufacturing process in which a liquid material is poured into a mold and allowed to solidify into a desired shape. The solidified part is also known as a casting.

  The mold is typically made of a heat resisting material such as sand, metal, ceramic, or silicone, and is designed to give the finished product a specific shape and size. The casting process is used to produce a wide variety of parts with complex shapes, such as engine blocks, gears, and pipes. It is a versatile process that can produce parts with high accuracy and good surface finish.

- Some Casting Terms:
  - **Flask**: A metal frame used to hold the mold in place during casting.
  - **Pattern**: A wooden or metal replica of the part to be cast. It is used to create the mold.
  - **Parting line**: The line where the two halves of the mold come together.
  - **Bottom board**: The bottom portion of the flask, on which the mold is formed.
  - **Molding sand**: A sand mixture that is used to create the mold. It must have good flowability and be able to hold its shape when packed around the pattern.
  - **Facing sand**: A fine-grained sand mixture used to create the surface of the mold.
  - **Backing sand**: A coarser-grained sand mixture used to support the facing sand and create the rest of the mold.
  - **Core**: A shaped piece of sand placed inside the mold to create internal cavities in the casting.
  - **Pouring basin**: A depression in the top of the mold where the molten metal is poured.

- **Sprue**: A channel that connects the pouring basin to the runner. It guides the molten metal into the mold. Its shape is ideally parabolic, but practically its shape is a tapered cylinder (in order to prevent the air aspiration effect).

- **Runner**: A channel that connects the sprue to the gate, which leads to the individual cavities in the mold.

- **Gate**: A narrow channel that connects the runner to the cavity in the mold. It controls the flow of molten metal into the mold.

- **Chaplets**: Small metal supports used to keep the core in place inside the mold. They are typically made of the same material as the casting and are left in the finished part.

- **Chill**: A metal or ceramic insert placed in the mold to rapidly cool a specific area of the casting.

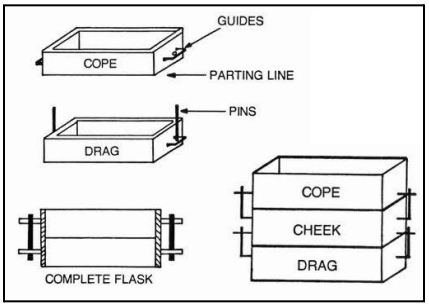
- **Riser**: A reservoir of molten metal attached to the casting. It feeds the casting as it solidifies and contracts.

- **Vent**: A small opening in the mold that allows gasses to escape during the casting process.

- **Cope**: The top half of a two-part mold used in the casting process. It is placed over the pattern and creates the top portion of the mold.

- **Drag**: The bottom half of a two-part mold used in the casting process. It is placed under the pattern and creates the bottom portion of the mold.

- **Dowel pins**: Metal pins used to align the cope and drag and ensure that they are properly aligned during the casting process.



- 6 Basic Steps in Casting Process:
    - **Pattern making**: The first step in making a sand casting is to create a pattern, which is a replica of the part to be cast. The pattern is used to create the mold and can be made of wood, metal, or plastic. The pattern must be an exact duplicate of the part, including any undercuts or other features.

    - **Core making**: If the casting has internal features, such as a hole or a passageway, a core must be made to create these features in the mold. The core is made of a special sand mixture that can be molded into the desired shape and is then baked to harden it.

    - **Molding**: Once the pattern and core are ready, the molding process begins. The molding sand, which is a mixture of sand, clay, and water, is packed around the pattern in the flask. The molding sand must have good flowability and be able to hold its shape when packed around the pattern. Once the sand has been packed, the pattern is removed, leaving a cavity in the sand in the shape of the part to be cast.

    - **Melting and Pouring**: The next step is to melt the metal that will be used for the casting. This is typically done in a furnace. Once the metal is molten, it is poured into the mold through a pouring basin, which is a depression in the top of the mold. The molten metal flows through the sprue, runner, and gate into the cavity in the mold.

    - **Cleaning**: Once the metal has solidified and the mold has been opened, the casting is removed and any excess material, such as the gates and risers, is trimmed off. The casting is then cleaned to remove any sand or other debris that may be adhering to its surface. This can be done mechanically or by hand.

    - **Finishing**: The final step in the casting process is to finish the casting as required. This may include machining, heat treating, or other operations to achieve the desired properties or finish.

- **Castability** refers to the ability of a metal or alloy to be cast into a desired shape without cracking, warping, or other defects. The castability of a metal or alloy is affected by its chemical composition, solidification characteristics, and the conditions of the casting process.

- Cast products generally may not have the same mechanical properties as wrought products because the grains of the metal do not align properly during the solidification process unlike the wrought products.

  However, with the development of new technologies, castability of some alloys is improved and the mechanical properties of cast products are continuously being improved.

- The below given materials can be used for making a Pattern:
  - Wood
  - Metals
  - Alloys
  - Plastics
  - Rubbers
  - Plaster of Paris
  - Wax
  - Resin

- A pattern material used in the casting process should have the following properties:
  - Accuracy.
  - Light-weight.
  - Durability.
  - Ease of machining.
  - Shrinkage compensation.
  - Low Cost.
  - Availability.

- Pattern Allowances:
  - **Shrinkage (contraction) allowance**: This is an allowance made in the pattern to compensate for the shrinkage that occurs as the casting material cools and solidifies. There are two types of shrinkage:
    - Liquid shrinkage, which occurs as the metal solidifies.
    - Solid shrinkage, which occurs as the metal cools.

  - **Draft (taper) allowance**: This is an allowance made in the pattern to allow for the removal of the pattern from the mold. A draft is typically added to the vertical walls of the pattern, tapering them slightly outward. This allows the pattern to be easily withdrawn from the mold without damaging it.

- **Machining (finishing) allowance**: This is an allowance made in the pattern to allow for the machining of the casting after it has been poured. It is typically added to all surfaces that will be machined, allowing for the removal of excess material and the achievement of the desired finish.

- **Distortion allowance**: This is an allowance made in the pattern to compensate for any distortion that may occur during the casting process. Distortion can be caused by a variety of factors, such as the type of metal being used, the casting temperature, or the cooling rate.

- **Shaking (negative) allowance**: This is an allowance made in the pattern to compensate for the shrinkage that occurs in the cope and drag during the shaking out process, in which the sand is removed from the mold after the casting has been poured. It is typically added to the pattern in the areas that will be most affected by the shrinkage.

- Types of Pattern: (**https link**)
  - **Single piece pattern**: A pattern that is made in one piece and is used to create a single cavity mold.

  - **Split pattern**: A pattern that is made in two or more pieces and is used to create a mold with multiple cavities. The pattern is split along the parting line of the mold.

  - **Gated pattern**: A pattern that includes gates, which are channels that allow the molten metal to flow into the mold.

  - **Cope & Drag pattern**: A pattern that is made in two halves, a cope and a drag, which are used to create a two-part mold. The cope is the top half of the mold and the drag is the bottom half.

  - **Match plate pattern**: A pattern that is mounted on a plate, with the pattern for one side of the casting on one side of the plate and the pattern for the other side on the other side. The plate is used to create a two-part mold, with the patterns facing each other.

  - **Loose piece pattern**: A pattern that is not attached to the primary pattern and can be removed from the mold after the mold cavity is formed.

    - **Follow board pattern**: A pattern that is mounted on a board and is used to create a mold with a curved surface. The board is bent to the desired shape and the pattern is mounted on it.

    - **Sweep pattern**: A pattern that is used to create a mold with a complex curved surface. It is shaped like a sweep, with a handle at one end and the pattern at the other.

    - **Skeleton pattern**: A pattern that is made of a lightweight frame and is used to create a mold for a large casting. The frame is filled with sand to create the mold.

- **Green sand molding** is a process in which a mold is formed from moist sand. The "green" in the name refers to the fact that the sand is not dried or baked before being used to create the mold. The molding sand is a mixture of silica sand, clay, and water. The sand is packed around a pattern, which is a replica of the part to be cast, and then the pattern is removed to create the mold. The mold is then used to cast the part in the desired material.

- Pros of green sand molding include:
    - It is a simple and inexpensive process, making it suitable for small-scale production or prototyping.

    - The process is highly adaptable, making it possible to create molds with a wide range of shapes and sizes.

    - Green sand molding allows for relatively high production rates.

    - The process results in minimal distortion and good surface finish.

- Cons of green sand molding include:
    - The molds have a limited lifespan, typically only good for one pour.

    - The process is not suitable for casting alloys that require high temperatures or specialized equipment.

    - The process is labor-intensive, and the molds need to be made by hand.

    - The process produces large amounts of waste sand and requires a lot of space for the storage and handling of sand.

    - The process also has a potential to create hazards to the environment as well as the health of the worker because of the release of dust.

- Sand mold making procedure:
    - Create a pattern of the desired object using wood, metal, or plastic.
    - Place the pattern in a box filled with sand and compact the sand around the pattern to create a mold.
    - Remove the pattern from the sand mold.
    - Apply a thin coat of parting agent to the mold to prevent the two halves of the mold from sticking together.
    - Create the second half of the mold in the same way as of the first mold.
    - Remove the two halves of the mold from the box and join them together to form a complete mold.
    - Use the mold to cast the desired object using metal or plastic.

- Pros of Shell Molding:
    - High precision and accuracy
    - High production rate.
    - Low tooling cost.
    - Versatile.
    - Good surface finish.

- Cons of Shell Moulding:
    - Limited to small and medium-sized parts.
    - High material cost.
    - Limited to ferrous metals.
    - Require high temperatures.
    - Requires finishing work.

- **Precision investment casting**, also known as **lost-wax casting**, is a process used to produce highly accurate and detailed metal parts. The steps for precision investment casting are:

    - Create a pattern of the desired object using wax or another similar material through injection molding that can be easily melted or burned out.

    - Create a ceramic mold around the pattern by dipping it in a slurry of fine ceramic particles and allowing it to dry.

    - Repeat the dipping process several times to build up the thickness of the ceramic mold.

    - Remove the wax pattern by heating the mold using 120°C steam to melt or burn out the wax in an autoclave.

    - Pour molten metal into the ceramic mold to cast the desired object.

    - Allow the metal to cool and solidify.

    - Remove the ceramic mold by breaking it off the cast object.

- Pros of Precision Investment Casting:
    - High precision and accuracy.
    - Complex geometry.
    - Good surface finish.

- Cons of Precision Investment Casting:
    - Long lead time.
    - Fragile.

- Fine grained cast iron, alloy cast iron, C20 steel and alloy steels (H11 and H14) are commonly used materials for the Permanent or Metal mold. The molds are coated with refractory materials to a thickness of 0.8 mm before casting.

- Pros of Permanent or Metal Molding:
    - High production rate.
    - Long-lasting.
    - Good dimensional accuracy.
    - High temperature resistance.

- Cons of Permanent or Metal Molding:
    - High tooling costs.
    - Limited to small and medium-sized parts.

- High temperature requirement.
- Limited to ferrous metals.
- Difficult to repair.

- Molding Sand Properties:
  - **Refractoriness**: Refractoriness refers to the ability of the sand to withstand high temperatures without breaking down or deforming. The higher the refractoriness of the sand, the better it will be able to withstand the high temperatures encountered during the casting process.

  - **Permeability**: Permeability refers to the ability of the sand to allow gasses and liquids to pass through it. Good permeability is important in allowing gasses to escape from the mold during the casting process, while still maintaining the shape of the mold.

  - **Green Strength**: Green strength refers to the strength of the sand when it is in its "green" state, meaning it is still moist and has not been baked or hardened. A sand with high green strength will be able to maintain its shape and resist deformation during the casting process.

  - **Dry Strength**: Dry strength refers to the strength of the sand after it has been dried or baked. A sand with high dry strength will be able to maintain its shape and resist deformation after the casting process.

  - **Hot Strength**: Hot strength refers to the strength of the sand at high temperatures. It's important for the sand to have good hot strength so that it can withstand the high temperatures encountered during the casting process without breaking down or deforming.

  - **Collapsibility**: Collapsibility refers to the tendency of the sand to shrink and collapse during the casting process. A sand with low collapsibility will be able to maintain its shape and resist deformation during the casting process.

- **Grain Fineness Number (GFN)** is a measure of the average size of the sand grains in a molding sand mixture. It is used to indicate the fineness of the sand mixture and its suitability for a particular casting process.

  A lower GFN value indicates a coarser sand mixture with larger grain size, while a higher GFN value indicates a finer sand mixture with smaller grain size.

- **Permeability number** is defined as the rate of flow of air passing through a standard specimen under a standard pressure.

- Sand Sources for Sand Mold:
    - Sea Shores
    - Rivers
    - Lakes
    - Deserts
    - Granular Elements Of Rocks

- Constituents of Synthetic Sand:
    - Silica Sand (85-91%)
    - Binder (6-11%)
    - Moisture (2-8%)

- Types of Molding Sand:
    - **Silica Sand**: It's the most commonly used type of molding sand used in the casting industry.

    - **Zircon Sand**: It's a mineral sand made of the mineral zirconium silicate. It's used for casting metals that require high pouring temperatures.

    - **Olivine Sand**: It's a natural sand made of the mineral olivine. It's used for casting steel and high alloyed steels and iron.

- **Binder** is a substance that is added to the molding sand to hold the sand particles together and give the mold its shape and strength. Binders are used to make the molding sand more cohesive, so that it can be packed around a pattern and retain its shape.

- Types of Binders:
    - **Organic Binders** are used to improve green strength, collapsibility, and adhesiveness properties. They are known for their flexibility and easy removal after casting, which makes them suitable for core making.

      Ex: Dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde, etc.

    - **Inorganic Binders** are used to improve refractoriness, thermal stability, and corrosion resistance properties and are suitable for use in molding sands for casting metals that require high pouring temperatures.

Ex: Clay, sodium silicate, portland cement, etc.

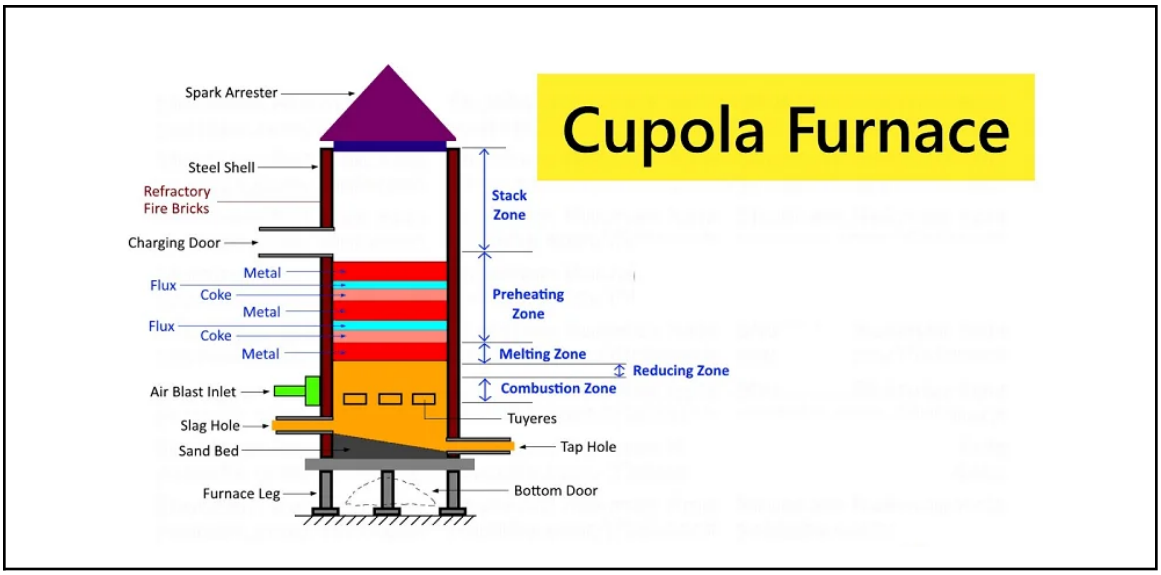
- In the foundry industry, ***clay*** is commonly used as a binder in molding sands and cores. There are several types of clay that can be used as binders in the foundry industry, including:
    - Kaolinite.
    - Ball clay.
    - Fire clay.
    - Limonite.
    - Fuller's earth.
    - Bentonite (most commonly used clay type).

- Green compressive strength first increases with the increase in clay content because the clay particles act as a "glue" that holds the sand particles together, providing the strength and cohesion necessary to maintain the shape of the mold.

  But after a certain point, the increase in clay content causes the clay particles to crowd each other and reduce the amount of bonding between the sand particles, resulting in a decrease in the green compressive strength.

- **Additives** are the substances that are used to improve the properties of the molding sand and make the casting process more efficient and produce better quality parts. The additives used are:
    - Coal dust.
    - Corn flour.
    - Dextrin.
    - Sea Coal.
    - Pitch.
    - Wood flour.
    - Silica flour.

- **Cupola furnace** is a type of furnace that is commonly used in the foundry industry for melting iron. It is a tall, cylindrical furnace that is lined with refractory bricks and has an opening at the top for charging the furnace with raw materials and an opening at the bottom for tapping the molten metal. Cupola furnace is fueled by coke, which is ignited at the bottom of the furnace and burns upward to heat the metal.



- **Electric Arc furnace** is a type of furnace that uses an electric arc to heat and melt metal. It consists of a refractory-lined steel vessel that is filled with metal, and is typically used for melting and refining steel. Here, the arcing is always done in reduced environments.

  The commonly used electrodes are:
  - Graphite electrodes.
  - Carbon electrodes.

- The 2 types of Electric Arc Furnace are:
  - In **Direct Arc Furnace**, the metal scrap itself acts as an electrode (anode) & exchange charges with the primary electrode (cathode), thus creating an arc & thereby heating & melting itself.

  - In **Indirect Arc Furnace**, the metal scrap itself doesn't act as an electrode. Instead, the arcing is done between 2 graphite or carbon electrodes away from the scrap metal, thereby generating & transmitting the heat to the metal scrap in the form of radiation.

- **Electric Induction Furnace** is a type of furnace that uses alternating electrical current to produce an alternating electromagnetic field that induces an eddy current in the metal to be melted. This causes the metal to heat and melt, and is typically used for melting small quantities of metal.

- The 2 types of Electric Induction Furnace are:
  - Cored Induction Furnace.

    - Coreless Induction Furnace.

- Coreless Induction Furnace is effective for melting Tungsten.

- The differences between Cored & Coreless Induction Furnace are as follows:

Cored Induction Furnace	**Coreless Induction Furnace**
Metal scrap itself acts as a secondary coil.	Metal scrap itself acts as a secondary coil.
Ferromagnetic core is used to concentrate the magnetic field.	No ferromagnetic core is used to concentrate the magnetic field. Instead, the metal scrap itself acts as a core.
The primary coil is housed inside a ceramic block & is placed inside the furnace.	The primary coil itself is wound around the outer surface of the furnace.

- **Electric Resistance Furnace** is a type of furnace that uses heating elements like Ni-Chrome outside the furnace to produce heat when electricity is passed through, thereby heating & melting the metal placed in the furnace.

- **Gating System** is a part of the casting process that controls the flow of molten metal into a mold. It's made up of various components, including:
    - Pouring Basin or Ladle.
    - Sprue.
    - Sprue Base Well.
    - Runner.
    - Runner Extension.
    - Ingate.
    - Riser.

  The *pouring basin or ladle* is the container that holds the molten metal and is used to pour it into the mold. The *sprue* is the opening through which the molten metal enters the mold and it is connected to the pouring basin or ladle. The *runners* are channels that distribute the molten metal from the sprue to the *gates*, which are the openings that allow the molten metal to flow into the mold cavities. *Risers* are also an important part of the gating system. They are the reservoirs that feed molten metal to the casting as it solidifies, in order to compensate for the shrinkage that occurs during solidification.

- **Pouring Time** refers to the amount of time that it takes for the molten metal to be poured into the mold.

  A short pouring time can lead to a casting with a poor surface finish, high levels of porosity, and a greater risk of defects such as cold shuts. A long pouring time can lead to the metal solidifying before it has had a chance to fill the mold completely, resulting in incomplete castings. Thus, the pouring time should be optimized so that the metal is poured into the mold quickly enough to avoid defects such as porosity and cold shuts, while also allowing enough time for the metal to flow evenly into the mold and fill all the cavities completely.

  In addition, the pouring time is also controlled by the pouring temperature of the metal. An ideal pouring temperature for a specific metal or alloy is the temperature that gives the best fluidity and feeding ability without causing any thermal cracking.

- **Choke Area**, also known as the constriction, is a part of a gating system in a casting mold that controls the flow of molten metal into the mold.

  It is typically located at the point where the sprue and the runner meet, and is designed to reduce the cross-sectional area of the gating system to create a restriction or bottleneck that helps to regulate the flow of metal into the mold.

- The main function of a pouring basin is to reduce the momentum of the liquid flowing into the mold by settling first into it.

- The sprue base well area should be 5 times that of the sprue choke area, and the well depth should be approximately equal to that of the runner.

- The gating ratio is defined as the ratio between the cross-sectional area of the sprue, the runner, and the gates in a gating system of a casting mold. (Gating Ratio = S:R:G)
  - **Non-Pressurized (For Non-Ferrous):** Here, the typical gating ratio is 1:4:4.

  - **Pressurized (For Ferrous):** Here, the typical gating ratio is 1:2:1.

- **Ingate** is defined as a weir with no reduction in cross-section of the stream at the gate.

- Slag Trap System are created using 2 methods:

- By using "Runner Extensions".
- By using "Whirl Gates".